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THE GRIT IN INNOVATION
– A RIGOROUS PURSUIT OF CREATIVE PROBLEM SOLVING

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PAPER ABSTRACT: The creative process in problem-solving has been a domain filled with studies across disciplines. Through an examination of the innovative practice of designers, engineers, and other professionals, a framework was developed to structure teaching and learning in the context of an undergraduate design studio in an industrial design program. The framework was tested and refined through a design studio. Specifically, it was applied to the same design challenge for a consecutive 5 years. Every year, a class of junior students was guided by the sequential steps of the framework. The student's creative process from the early infantry of an idea to a fully developed design was carefully documented and analyzed. Surveys and group discussions were organized at the end of the project to collect students' feedback. Deliberation of students' successes and failures sheds light on an optimized process with an emphasis on the gritty caliber threading through students' process of work that achieves quality innovation.

Keywords: creativity, innovation, grit, inspiration, fixation.

1. INTRODUCTION

Creativity has been a driving force of human civilization. As the most unique human trait, creativity is hard to be defined. At large, creativity is considered a novelty-generating process in the biological world or the universe. The definition proposed by Guilford over sixty years ago has been universally converged upon: originality and appropriateness in relevance to the task domain (Gabora, 2013). Dr. George Land devised a creativity test for NASA to help select innovative engineers and scientists in the 1960s. The assessment worked so well that he decided to try it on children. In 1968, a research study was conducted to test the imaginative thinking of 1,600 children ranging in age from three to five years old. He re-tested the same children at 10 years of age, and again at 15 years of age. The testing result was astounding. The result of the sequential tests is shown in Figure 1. Among 4-5 years old, 98% of them were excellent at a 'genius' level in imaginative thinking. When they grew to 10 years of age, that number reduced drastically to 30%. When they grew to 31 years of age, their imaginative thinking skill has been almost completely wiped out. "what we have concluded," Land wrote, "is that non-creative behavior is learned." (Land, Jarman, 1998).

Test results amongst 4-5 years old:	98%
Test results amongst 10 years old:	30%
Test results amongst 15 years old:	12%
Test results amongst 31 years old: (over 1,000,000 tested)	2%

Figure 1. Imaginative Thinking test by Dr. George Land in 1998.

This startling study signifies that when we were young, virtually everyone was a genius with creative potential. But over years of growing and learning, our creativity is diminished or killed in the process! Dr. Ken Robinson shared a similar view addressing the profound failure of our education system for cultivating students' creativity. He argued that our outmoded industrial educational system and structure are designed to slowly 'educate' us out of our creative capacity. He proposed a personalized approach to engage students in discovering and developing their passion for learning (Robinson, Aronica, 2015).

Realizing that the traditional education system mostly fails to cultivate students' creativity begs a question: is it possible to bring students' creative capacity back so that they will regain some imaginative thinking at five years old? If it is possible, then how? The answer is yes. Creative thinking is a deliberate process. Creativity is a skill that can be developed and a process that can be managed. Some training programs intended to develop creative capacities have been proposed and proven for their effectiveness (Scott, Leritz, Mumford, 2004).

1.1 KEY COMPONENTS OF CREATIVITY

One of the most recognized theories is a set of key components of creativity developed by Dr. Amabile who is a psychologist specializing in creative studies. Dr. Amabile predicted and approved that three major components contribute to creativity: expertise in the task domain, creative thinking skills, and motivation (Conti, Coon, Amabile, 1996).

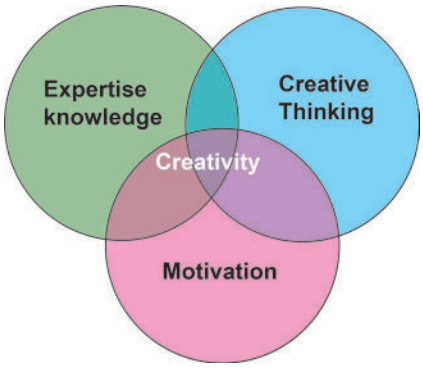

Figure 2. Three major components of creativity.

The diagram in Figure 2 depicts the supportive relationships among three components. Creativity begins with a foundation of knowledge, learning a discipline, and mastering a way of thinking. Expertise is about knowledge, technical procedural, and intellectual skills in the task domain. Creative thinking skills are about experimenting, exploring, questioning assumptions, using imagination, and synthesizing information. Creative thinking is across domains and includes cognitive style, working style, and divergent thinking abilities. Task motivation is about motivational variables that influence and drive an individual's performance. These three components imply a basic skeleton of an innovation framework.

1.2 DIVERGENT VERSUS CONVERGENT THINKING

One of the effective creative thinking skills is the divergent and convergent thinking practice which is often inadequately or mistakenly addressed in creative teaching (Macuare, 2016). Divergent thinking is the generation of a variety of ideas and alternative solutions to problems (Guilford, 1968). Accumulated research work and evidence suggest that divergent thinking is the cognitive basis of creative thoughts (Sio, Kotovsky, Cagan, 2015). Neuroscientists utilize brain imaging to study the brain's activeness during different stages of thinking. The brain imaging scans show that our brain is much more active across all zones under the divergent thinking stage compared to the normal stage in which divergent and convergent thinking are mixed in the process (Fig. 3). The brain imaging also shows that the highly creative individuals' brain is more active in more areas compared to the low creative individuals (Wu, et, al. 2020).

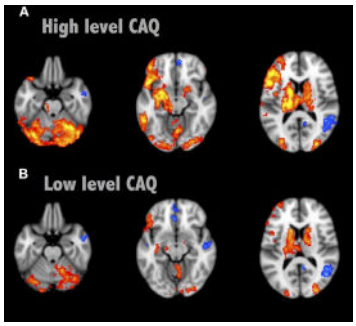

Figure 3. Brain activation map under divergent thinking or conventional thinking (Wu, et, al. 2020).

2. METHOD

As emphasized in the four stages of a creative process (Gregoire, 2019), productive preparation and incubation are essential in carrying out a successful innovation. As Einstein shared about creativity in problem-solving: “Imagination is more important than knowledge”, how to lead students to be inspired and engaged with imagination is a critical basis for innovation.

2.1 SOURCES OF INSPIRATION

One of the first steps in preparation is to identify inspiring sources. Based on the relationship to the task subject or domain, the inspiring sources are categorized into three kinds: distant, mid, and near sources in a diagram as shown in Figure 4. Near source of inspiration is information or subjects that are in the same category as the task subject. It is closely associated with the task domain. Mid source of inspiration is information or subjects that are in different but similar categories as the task subject. Distant sources are not related to the category of the tasked subject. Using a tangible subject as an example, if the task is to design a vehicle, all vehicles belong to the near sources of inspiration. Mid sources of inspiration are transportation tools or machines such as trains, aircraft, boats, etc. Distant sources are information and subjects that are far different from the vehicle or the transportation such as natural creatures, plants, or anything else. It can be a flying eagle, a swing tree in the wind, or a piece of music.

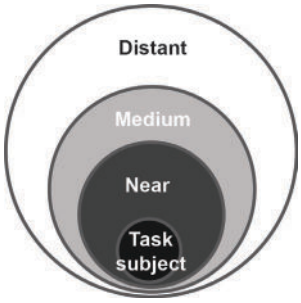

Figure 4. Sources of inspiration concerning the task domain.

2.2 A FRAMEWORK FOR INNOVATION

Based on the original framework presented (Feng, 2020), the process is refined with more emphasis on the sources of inspiration and three key components of creativity: expertise, creative thinking, and motivation (Fig. 5). The inspiration is devised and managed in three categories of distant, mid, and near sources to provide a systematic and easy-to-follow structure for students' design preparation. Intentionally designing a procedure or a space for students to explore and discover their interests is an effective way of motivation as evidenced in previous studies. The process starts with an exploration of inspiration sources. Sequentially, students are led to explore the distant inspiration first. It is about what they like to do and what they like to see. Not only will they be motivated by what they uncovered, but also, they will less likely to be influenced and confined by the task subjects from near inspirational sources. Then they will be led to explore mid and near sources of inspiration through which they will gain knowledge and develop their expertise in the task domain.

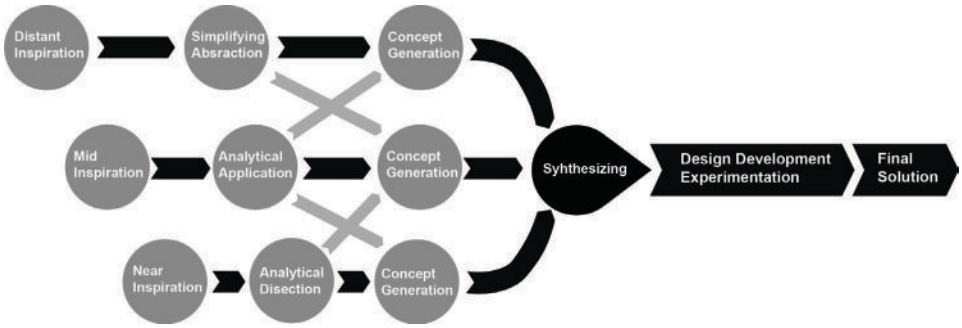

Figure 5. A creative problem-solving process to maximize inspiration opportunities.

Multiple practices are deployed to facilitate creative thinking exploration. Imageboard constructed with key attributes helps students to illustrate and document their inspiration sources. Sketching abstraction exercise helps them to simplify and capture the inspiration sources into basic visual elements. Analytical dissection helps students to learn valuable details relating to the subject in terms of technologies, materials, mechanics, etc. Divergent preliminary concept generation helps students to maximize the quantity and the range of novel ideas. In this phase, multiple steps are designed to guide them to connect ideas and elements across sources into concepts. Convergent synthesizing guides them to consolidate and integrate the best ideas into a few more developed concepts. Design experimentation helps them to advance the design concept into a solution that is original, appropriate, and feasible.

3. CASE STUDY: THE GRIT & THE PERFORMANCE

Over five years, this innovation framework has been originated and applied to the same project in an industrial design junior studio in the fall semester. Every year the process

was examined for refinements. The design challenge is to design a chair with a set of criteria as follows:

- A chair of the original design should be aesthetically pleasing.
- Create an offering that can be marketed in the context of residential and/or contract trade.
- Any material or combination of materials will be accepted.
- The chair should be appropriate for manufacturing, fiscally feasible, and suitable for mass production.

3.1 THE GRIT IN INSPIRATIONAL RESEARCH

Students were guided to start by exploring distant sources of inspiration with the exclusion of chairs. It is about their passion for design and what interests them the most through the five senses visual, audio, tactile, smell, and taste. First, they described their interests with key attributes, then the attributes were represented by images composed on an image board. They were prohibited to use any chair references in this exercise. It was a struggle for most students at the beginning because they have not been tasked to conduct such a self-discovery exercise before. Some students did not know what they like. Gradually, they started questioning themselves critically. In projects of designing a tangible product such as a chair, exploring the inspiration references is much more than an image board but a soul-searching inquiry for interest and beauty. It is about the depth and breadth of searching through a high quantity of elements across all things.

Two students' image boards are shown in Figure 6. Key attributes of the left one are unity, dynamic, power, texture, and vividness. Attributes of the right are mysterious, intricate, flowing, and gentle texture. Both collections are successful in capturing students' interest with rich visual elements. Their imaginative minds were activated through the exercise.

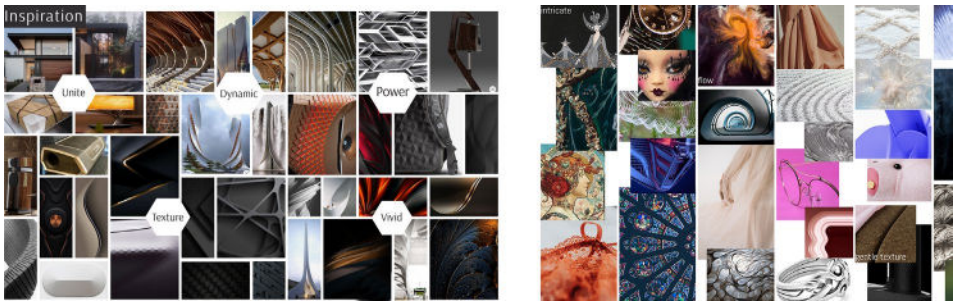

Figure 6. Visual reference samples of distant sources of inspiration.

Collected projects over the years show that even in this early stage students' performance indicates and determines their projects' future outcomes. There is a clear difference between the more inspired student's presentation and the displays by students who were skeptical and failed to identify their sources of inspiration. Some

students dedicated more time to select high-quality visual sources carefully to capture their interests. Some students took minimal time to put a board together with a few images from the internet. The level of inspiration varied in a wide range.

3.2 THE GRIT IN VISUAL ABSTRACTION

Capturing the essence of inspirational sources is the next step. The inspiration sources, visual samples in this case, usually present in a mixed form of shapes, patterns, colors, compositions, and more elements. As shown in Figure 6, a part of a building contains many visual elements. The question is what is the intriguing element? The sketching abstraction process is designed in two sequential steps. The first step is to simplify visual samples into basic elements of forms, shapes, lines, and dots that are truly attractive to them. Once they have a collection of abstractions, students were asked to choose elements from the collection to form shapes and surfaces that can be sat on. Successful sketching abstraction captures the key visual elements in simple forms that serves as a pool of elements calling for ideas (Fig. 7). The clear and meaningful connection from the original inspirations to the abstractive sketches and initial concepts contributes to the liberating novelty in concepts. This process demands efforts in analytical thinking and practice. Failed exercises showed disconnections among steps and the attributes of inspiration were not captured and transformed into concepts. New ideas are not coming out of thin air. If students are not inspired through the research phase, it will be almost impossible to high-quality concept generation.

Figure 7. A sample of idea transformation from inspiration visuals to the initial concepts.

3.3 THE GRIT IN CONCEPT GENERATION AND SYNTHESIS

Concept generation contains two sequential steps divergent idea generation and convergent concept synthesis. In the divergent phase, the range and the number of concepts are two calibers to measure the quality of innovation. The range of concepts is about the spectrum of differences among concepts. Some students generated a high number of concepts with low distinctions among them, most are variations of a few ideas. These students likely miss the opportunity to exercise their brains ‘creative muscles’ in the breadth of thinking. On the other side, some students understood the values of divergent thinking and generated a range of

ideas with clear distinctions among them. The originality is often higher among the concepts of these students.

The quality of concept generation is often influenced by the outcome of the previous steps. Students who performed well are likely more inspired by a rich basis of ideas for their concept generation. It becomes a natural and enjoyable process for them to transform abstractions into concepts. On the other side, concept generation can turn into a struggle for students who were not quite inspired through the first and second steps. These students are often the ones who did not produce quality abstractions. Figure 8 shows a student's work from the inspiration source of the dancer's flowing line to the final design. The dancer's movement was captured from the beginning and carried out through the concept development process to be an outstanding design.

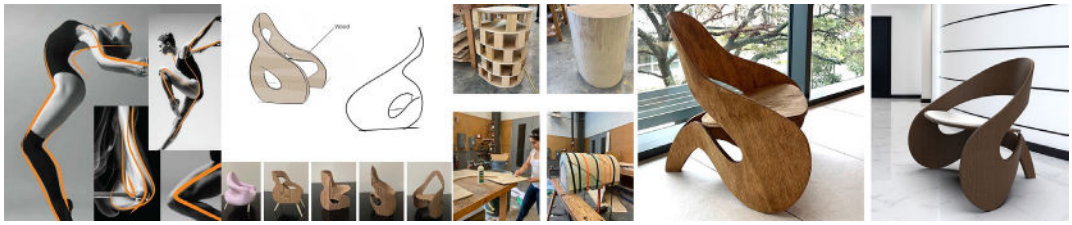

Figure 8. A sample of idea transformation from inspiration visuals to the final design.

3.4 THE GRIT IN DESIGN DEVELOPMENT

Once the final concept is synthesized from the best ideas, students moved on to the design development phase. The challenge in this phase is to develop the concept into a final product without compromising and losing the original idea. The process demands rigorous effort in bringing the design to a finished state in terms of functionality, structure and mechanisms, materials and finishes, and refined details. Figure 9 shows another project from the early inspiration of a flower to the fully developed design. The student developed countless scale models to perfect the size, proportion, and sitting ergonomics. To achieve high consistency in organic curvatures, multiple gigs were developed to shape each wire in consistent curves. Hundreds of welding spots were polished before painting. The final design is impossible without the students' relentless effort in the building process.

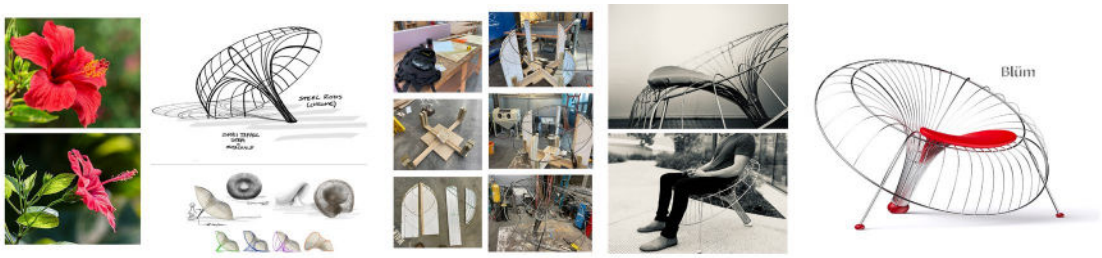

Figure 9. A successful process from the early inspiration to the final design prototype.

4. DISCUSSION AND FUTURE WORK

Over five years, as a third party's assessment, the work of this studio has been recognized in international and national competitions for originality and aesthetic quality in design. Most recently, the chair "Blüm" as shown in Figure 9 won first place in the ISFD (the International Society of Furniture Designers) Pinnacle Award in 2022. The chair "Siva Afi" as shown in Figure 8 won first place in another national furniture design competition in 2023. This studio has claimed three first places and one-second place in this competition in the last five years.

Every year, feedback was collected from students right after the project through surveys and discussions. Table 1. shows the students' average ratings about the creative process concerning their performance over the last four years with a total of 83 participants. While the overall rating is in the 7.5 - 8.5 range regarding the effectiveness of inspiration, most students agree that the process helps them to generate more novel ideas. This is consistent with the professional jury's assessment which rated the originality and the aesthetic quality at an excellent level.

Table 1. The mean ratings of the survey over four years (rating scale of 1 to 10, 83 participants).

Questions	Ratings
The inspiration board's effectiveness to identify my passion for design	8.5
The effectiveness of sketching abstraction process to visualize the inspirations	7.5
The sketching process from inspiration to initial concepts is easy to follow	8. 5
The process to generate a large number of concepts	9
The process to generate high-quality concepts	8.75

In addition to the survey, class-wide discussions were organized to collect students' unique experiences for improvement. Most students enjoyed the thought process of visualizing their interests. They agreed that the distant, mid, and near sources of inspiration were effective practices to cultivate their creative minds. The students' work shows that the distant sources contribute more to the idea novelty versus the near

sources assist more to the quality of design in the refinement with details. There was a splitting view of the sketching abstraction process. Some felt it was very helpful to open up their mind to ideas. Some did not think it contributed much to new ideas.

Students' performance displays a consistent spectrum over the years from the strong performers to the low performers. They are from the highly inspired ones to the least touched few. Every individual is different. No innovation process fits all. This reality calls for more exploration of the ways to inspire and engage students in their creative process. Design fixation is another challenge that has been witnessed over the years. Driven by the fear of failure and staying within their comfort zone, some students fixed their designs on a conventional form of a chair early on and were reluctant to any deviation from it through the process. How to help these students to break the preexisting molded minds calls for more experimentation. The framework's core values of motivation development, critical thinking practice, and expertise building suggest an application potential in varied academic fields as well as professional practice.

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